

**REMARKS**

Favorable reconsideration and allowance of all pending claims in view of the following remarks is respectfully requested.

Claims 1-75 are pending in this application.

The Examiner has rejected Claims 1-75 under 35 U.S.C. §102(b) as being anticipated by Valcho et al. U.S. Patent No. 4,601,837 ("Valcho et al."). This rejection is respectfully traversed.

Valcho et al. fail to disclose a stable colloidal suspension comprising "(a) a dispersed phase comprising *a major amount of one or more dispersed hydrated polymeric compounds selected from ... polymolybdates ...* and, (b) an oil phase comprising one or more dispersing agents and a diluent oil" as generally recited in independent Claims 1, 18 and 43.

It is well established that for a prior art reference to evidence lack of novelty (anticipation) of the subject matter of a claim under 35 U.S.C. §102, each and every element as set forth in the claim must be either expressly or inherently described in a single prior art reference. *Verdegall Brothers, Inc. v. Union Oil Co. of Cal.*, 814 F.2d 628, 631, 2 USPQ2d 1051, 1053 (Fed. Cir.), *cert. denied*, 484 U.S. 827 (1987).

In the Office Action, the Examiner states that "Valcho discloses solutions or dispersions made by mixing hydrated polymolybdates and oil where the polymolybdate is the major part of the dispersed phase and which may include polybutene succinic anhydride to improve clarity". The Examiner goes on to state that "[i]t would appear that the conditions using molybdenum oxides and acids of the patentee with heating would be sufficient to give the polymerizations required of the instant claims."

In contrast to the presently claimed invention, Valcho et al. disclose a process for the manufacture of an *overbased molybdenum-alkaline earth metal sulfonate* by (a) introducing into a reaction zone a sulfonic acid, at least about 0.1 wt% of which is neutralized with ammonia; (b) adding a substantially inert diluent, an alkaline earth metal compound, an alkanol having from one to seven carbon atoms, and water to the reaction zone to form a hydration mixture; (c) heating the hydration mixture to an elevated temperature to hydrate the alkaline earth metal compound to produce an alkaline earth metal hydroxide hydrate; (d) adding an acidic material to the reaction zone at a temperature within the range of about 26.7°C (80°F) to about 68.5°C (155°F); and (e) adding a molybdenum-containing compound to the reaction zone at a time in the process that is subsequent to the introducing of a sulfonic acid and prior to adding of an acidic material to form the molybdenum-alkaline earth metal sulfonate. Valcho et al. further disclose that the overbased molybdenum-alkaline earth metal sulfonate product will have a high Total Base Number (TBN) of at least 300. Accordingly, by overbasing the molybdenum-alkaline earth metal sulfonate, the pH of the product will be greater than 7.

However, at a pH of greater than 7, any polymolybdate present in the solution would necessarily breakdown into a non-polymeric molybdate. This is evidenced in, for example, Encyclopedia of Chemical Technology, “*Mass Transfer to Neuroregulators*”, Fourth Edition, Volume 16, pp. 940-942 (1995) (Exhibit 1) which states that “In aqueous solution the behavior of Mo(VI) is extremely pH-dependent. Above pH 7 molybdenum (VI) occurs as the tetrahedral oxyanion  $\text{MoO}_4^{2-}$ , but below pH 7 a complex series of concentration-, temperature-, and pH-dependent equilibria exist. The best known of these equilibria leads to the formation of the heptamolybdate,  $\text{Mo}_7\text{O}_{24}^{6-}$  ... and octamolybdate,  $\text{Mo}_8\text{O}_{26}^{4-}$ , ions.” As such, the overbased

molybdenum-alkaline earth metal sulfonate product disclosed in Valcho et al. would not contain (a) a dispersed phase comprising a major amount of one or more dispersed hydrated polymeric compounds selected from ... polymolybdates ... and, (b) an oil phase comprising one or more dispersing agents and a diluent oil. In contrast, the overbased product would simply be an overbased *molybdenum*-alkaline earth metal sulfonate. Accordingly, since Valcho et al. do not disclose a stable colloidal suspension comprising “(a) a dispersed phase comprising a major amount of one or more dispersed hydrated polymeric compounds selected from ... polymolybdates ... and (b) an oil phase comprising one or more dispersing agents and a diluent oil” as generally recited in independent Claims 1, 18 and 43, independent Claims 1, 18 and 43 are not anticipated by Valcho et al.

In addition, with respect to Claim 18, nowhere does Valcho et al disclose a “process for preparing a stable colloidal suspension comprising:

mixing, under agitation, (a) an aqueous solution comprising one or more hydrated polymeric compounds selected from the group consisting of polymolybdates, polytungstates, polyvanadates, polyniobates, polytantallates, polyuranates, and mixtures thereof; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 18.

Nor, with respect to Claim 43, does Valcho et al likewise disclose a “process for preparing a stable colloidal suspension comprising:

mixing, under agitation, an (a) aqueous solution comprising (i) one or more monomeric compounds selected from the group consisting of molybdenum, tungsten, and vanadium

containing compounds and (ii) an effective amount of an acid capable of at least partially polymerizing the one or more monomeric compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 43.

Nor, with respect to Claim 63, does Valcho et al likewise disclose a “process for preparing a stable colloidal suspension comprising:

mixing, under agitation, (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 63.

Rather, Valcho et al. simply disclose stirring the reaction mixture to prepare the overbased molybdenum-alkaline earth metal sulfonate. However, stirring alone would be insufficient to form a micro emulsion as presently recited in Claims 18, 43 and 63. This is evidenced in, for example, Colloidal Systems and Interfaces, “Processing Methods for Making Emulsions and Suspensions”, Chapter IE, pp. 56-61 (1988) (Exhibit 2) which generally states that high velocity is typically required to emulsify liquids and further states that a colloid mill, used to emulsify liquids, operates by rotating at speeds of 1,000-20,000 rpm. By subjecting the mixture of recited components (a)-(c) to agitation, as set forth in Claim 18, 43 and 63, a micro emulsion can be obtained, which, after heating to a temperature to remove sufficient water,

produces the claimed stable colloidal suspension. Certainly, then, the disclosure in Valcho et al. of simply stirring the reaction mixture to prepare the overbased molybdenum-alkaline earth metal sulfonate would not provide a micro emulsion as presently recited in Claims 18, 43 and 63. Accordingly, Claims 18, 43 and 63 are believed to be further patentable over Valcho et al.

Furthermore, with respect to Claim 63, nowhere does Valcho et al. disclose a “process for preparing a stable colloidal suspension comprising:

mixing, under agitation, (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension comprising (a) a dispersed phase comprising a major amount of a dispersed hydrated polymeric compound selected from the group consisting of *polyniobates*, *polytantalates*, and *polyuranates*; and, (b) an oil phase comprising the dispersing agent and the diluent oil” as presently recited in Claim 63.

Rather, Valcho et al. simply disclose that molybdenum compounds can be added to the reaction mixture to prepare overbased molybdenum-alkaline earth metal sulfonate. As there is no disclosure in Valcho et al. of mixing an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds, Valcho et al. could not possibly obtain a colloidal suspension comprising (a) a dispersed phase comprising a major amount of a dispersed hydrated polymeric compound selected from the group consisting of *polyniobates*, *polytantalates*, and *polyuranates*; and, (b) an

oil phase comprising the dispersing agent and the diluent oil as presently recited in Claim 63.

Accordingly, Claim 63 is believed to be further patentable over Valcho et al.

For the foregoing reasons, Claims 1-75 are believed to possess novel subject matter relative to Valcho et al. Thus, withdrawal of the rejection of Claims 1-75 under 35 U.S.C. §102 (b) is respectfully requested.

The Examiner has rejected Claims 1-75 under 35 U.S.C. §103(a) as being obvious over Valcho et al. This rejection is respectfully traversed.

Valcho et al. likewise provide no suggestion or motivation of a stable colloidal suspension comprising “(a) a dispersed phase comprising *a major amount of one or more dispersed hydrated polymeric compounds selected from ... polymolybdates ...* and, (b) an oil phase comprising one or more dispersing agents and a diluent oil” as generally recited in independent Claims 1, 18 and 43.

Rather, Valcho et al. disclose a process for the manufacture of an *overbased molybdenum-alkaline earth metal sulfonate*. Valcho et al. further disclose that the overbased molybdenum-alkaline earth metal sulfonate product will have a Total Base Number (TBN) of at least 300. Accordingly, by overbasing the molybdenum-alkaline earth metal sulfonate, the pH of the product will be greater than 7.

However, as stated above, at a pH of greater than 7, any polymolybdate present in the solution would breakdown into a non-polymeric molybdate. This is evidenced in Exhibit 1 which states that “In aqueous solution the behavior of Mo(VI) is extremely pH-dependent. Above pH 7 molybdenum (VI) occurs as the tetrahedral oxyanion  $\text{MoO}_4^{2-}$ , but below pH 7 a complex series of concentration-, temperature-, and pH-dependent equilibria exist. The best

known of these equilibria leads to the formation of the heptamolybdate,  $\text{Mo}_7\text{O}_{24}^{6-}$  ... and octamolybdate,  $\text{Mo}_8\text{O}_{26}^{4-}$ , ions.” Thus, nothing in Valcho et al. would lead one skilled in the art to modify the overbased molybdenum-alkaline earth metal sulfonate and arrive at the presently recited stable colloidal suspension comprising “(a) a dispersed phase comprising a major amount of one or more dispersed hydrated polymeric compounds selected from ... polymolybdates ... and, (b) an oil phase comprising one or more dispersing agents and a diluent oil” of independent Claims 1, 18 and 43. In fact, one skilled in the art would be led away by the disclosure in Valcho et al.

In addition, with respect to Claim 18, nowhere does Valcho et al provide any suggestion or motivation of a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, (a) an aqueous solution comprising one or more hydrated polymeric compounds selected from the group consisting of polymolybdates, polytungstates, polyvanadates, polyniobates, polytantalates, polyuranates, and mixtures thereof; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 18.

Nor, with respect to Claim 43, does Valcho et al provide any suggestion or motivation of a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, an (a) aqueous solution comprising (i) one or more monomeric compounds selected from the group consisting of molybdenum, tungsten, and vanadium containing compounds and (ii) an effective amount of an acid capable of at least partially

polymerizing the one or more monomeric compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 43.

Nor, with respect to Claim 63, does Valcho et al provide any suggestion or motivation of a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 63.

Rather, as stated above, Valcho et al. simply disclose stirring the reaction mixture to prepare the overbased molybdenum-alkaline earth metal sulfonate. However, stirring alone would be insufficient to form a micro emulsion as presently recited in Claims 18, 43 and 63. This is evidenced in Exhibit 2 which states that colloid mills are used to emulsify liquids and further states that the colloid mills operate by rotating at speeds of 1,000-20,000 rpm. By subjecting the mixture of recited components (a)-(c) to agitation, a micro emulsion can be obtained, which, after heating to a temperature to remove sufficient water, produces the claimed stable colloidal suspension. Certainly, then, the disclosure in Valcho et al. of simply stirring the reaction mixture to prepare the overbased molybdenum-alkaline earth metal sulfonate provides no suggestion, motivation or even a hint of forming a micro emulsion by subjecting the mixture



of recited components (a)-(c) to agitation and then heating the micro emulsion to a temperature to remove sufficient water and produce the claimed stable colloidal suspension as presently recited in Claims 18, 43 and 63. Accordingly, Claims 18, 43 and 63 are believed to be further patentable over Valcho et al.

Furthermore, with respect to Claim 63, nowhere does Valcho et al. provide any suggestion of motivation of a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension comprising (a) a dispersed phase comprising a major amount of a dispersed hydrated polymeric compound selected from the group consisting of polyniobates, polytantalates, and polyuranates; and, (b) an oil phase comprising the dispersing agent and the diluent oil” as presently recited in Claim 63.

Rather, Valcho et al. simply disclose that molybdenum compounds can be added to the reaction mixture to prepare overbased molybdenum-alkaline earth metal sulfonate. At no point is there any suggestion, motivation or even a hint in Valcho et al. of mixing (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds, with (b) one or more dispersing agents and (c) a diluent oil to form the recited colloidal suspension. In contrast, the primary goal of Valcho et al. was to find a solution of overbasing of magnesium. Thus, nothing in Valcho et al.

would lead one skilled in the art to modify the overbased molybdenum-alkaline earth metal sulfonate disclosed therein and arrive at a process to prepare a colloidal suspension comprising (a) a dispersed phase comprising a major amount of a dispersed hydrated polymeric compound selected from the group consisting of polyniobates, polytantalates, and polyuranates; and, (b) an oil phase comprising the dispersing agent and the diluent oil by "mixing, under agitation, (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and, heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension" as presently recited in Claim 63. Accordingly, Claim 63 is believed to be further patentable over Valcho et al.

For the foregoing reasons, Claims 1-75 are believed to be nonobvious, and therefore patentable, over Valcho et al. Accordingly, withdrawal of the rejection of Claims 1-75 under 35 U.S.C. §103 (c) is respectfully requested.

The Examiner has rejected Claims 1, 2, 5-11, 14-19, 22, 23, 26-35, 37, 39-44, 49, 51, 54-63, 69 and 72-75 under 35 U.S.C. §102(b) as being anticipated by Schreiber U.S. Patent No. 4,647,388 ("Schreiber"). This rejection is respectfully traversed.

Schreiber fails to disclose, *inter alia*, a "stable colloidal suspension comprising: (a) a dispersed phase comprising *a major amount of one or more dispersed hydrated polymeric compounds selected from ... polymolybdates ...* and, (b) an oil phase comprising one or more dispersing agents and a diluent oil" as generally recited in independent Claims 1, 18 and 43.

It is well established that for a prior art reference to evidence lack of novelty (anticipation) of the subject matter of a claim under 35 U.S.C. §102, each and every element as set forth in the claim must be either expressly or inherently described in a single prior art reference. *Verdegall Brothers, Inc. v. Union Oil Co. of Cal.*, 814 F.2d 628, 631, 2 USPQ2d 1051, 1053 (Fed. Cir.), *cert. denied*, 484 U.S. 827 (1987).

In contrast to the presently claimed invention, Schreiber discloses a lubricant additive obtained from the reaction product of a salt of a tertiary amine with ammonium molybdate and/or molybdic acid. Schreiber further discloses that the tertiary amine salt is preferably used in a mole ratio of 1:1 or more and, in particular, a weight ratio of tertiary amine salt to ammonium molybdate or molybdic acid of 50:20 to 70:40 and more preferably 60:25. Thus, by using a greater amount of tertiary amine salt as compared to the ammonium molybdate or molybdic acid, a significant amount of the tertiary amine salt will be present in the reaction product disclosed in Schreiber. As such, the suspension disclosed in Schreiber could not contain “(a) *a dispersed phase comprising a major amount of one or more dispersed hydrated polymeric compounds selected from ... polymolybdates ...* and, (b) an oil phase comprising one or more dispersing agents and a diluent oil” as generally recited in independent Claims 1, 18 and 43. Thus, Schreiber does not disclose all of the elements and limitations of the claimed invention. Accordingly, independent Claims 1, 18 and 43 are not anticipated by Schreiber.

In addition, with respect to Claim 18, nowhere does Schreiber disclose a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, (a) an aqueous solution comprising one or more hydrated polymeric compounds selected from the group consisting of polymolybdates, polytungstates,

polyvanadates, polyniobates, polytantalates, polyuranates, and mixtures thereof; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 18.

Nor, with respect to Claim 43, does Schreiber likewise disclose a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, an (a) aqueous solution comprising (i) one or more monomeric compounds selected from the group consisting of molybdenum, tungsten, and vanadium containing compounds and (ii) an effective amount of an acid capable of at least partially polymerizing the one or more monomeric compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 43.

Nor, with respect to Claim 63, does Schreiber likewise disclose a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 63.

Rather, Schreiber simply discloses a lubricant additive obtained from the reaction product of a salt of a tertiary amine with ammonium molybdate and/or molybdic acid. Schreiber further discloses that the lubricant additive according to the present invention is preferably present as a package in the form of a solution or suspension in a primary oil (mineral or synthetic oil) and is preferably sold and used in this form. Schreiber goes on to state in Example 2 that a lubricating agent package is produced by mixing 2 parts by weight of a reaction product obtained according to Example 1 (a) in mineral oil, 4 parts by weight of sulphonated ester and 2 parts by weight of zinc dithiophosphate. At no point in Schreiber is there any disclosure of the specifically recited steps of the process set forth in Claims 18, 43 and 63. Thus, Schreiber does not disclose all of the elements and limitations of the claimed invention and independent Claims 18, 43 and 63 are not anticipated by Schreiber. Accordingly, Claims 18, 43 and 63 are believed to be further patentable over Schreiber.

Furthermore, with respect to Claim 63, nowhere does Schreiber disclose a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension comprising (a) a dispersed phase comprising a major amount of a dispersed hydrated polymeric compound selected from the group consisting of *polyniobates*,

*polytantalates, and polyuranates*; and, (b) an oil phase comprising the dispersing agent and the diluent oil” as presently recited in Claim 63.

Rather, Schreiber simply discloses a lubricant additive obtained from the reaction product of a salt of a tertiary amine with ammonium molybdate and/or molybdic acid. As there is no disclosure in Schreiber of mixing, under agitation, an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds, Schreiber could not possibly obtain a colloidal suspension comprising “(a) a dispersed phase comprising a major amount of a dispersed hydrated polymeric compound selected from the group consisting of *polyniobates, polytantalates, and polyuranates*; and, (b) an oil phase comprising the dispersing agent and the diluent oil” as presently recited in Claim 63. Accordingly, Claim 63 is believed to be further patentable over Schreiber.

For the foregoing reasons, Claims 1, 2, 5-11, 14-19, 22, 23, 26-35, 37, 39-44, 49, 51, 54-63, 69 and 72-75 are believed to possess novel subject matter relative to Schreiber. Thus, withdrawal of the rejection of Claims 1, 2, 5-11, 14-19, 22, 23, 26-35, 37, 39-44, 49, 51, 54-63, 69 and 72-75 under 35 U.S.C. §102 (b) is respectfully requested.

The Examiner has rejected Claims 1, 2, 5-11, 14-19, 22, 23, 26-35, 37, 39-44, 49, 51, 54-63, 69 and 72-75 under 35 U.S.C. §103(a) as being obvious over Schreiber. This rejection is respectfully traversed.

Schreiber likewise provides no suggestion or motivation of a stable colloidal suspension comprising “(a) a dispersed phase comprising *a major amount of one or more dispersed hydrated polymeric compounds selected from ... polymolybdates ...* and, (b) an oil phase comprising one

or more dispersing agents and a diluent oil” as generally recited in independent Claims 1, 18 and 43.

Rather, Schreiber discloses a lubricant additive obtained from the reaction product of a salt of a tertiary amine with ammonium molybdate and/or molybdic acid. Schreiber further discloses that the tertiary amine salt is preferably used in a mole ratio of 1:1 or more and, in particular, a weight ratio of tertiary amine salt to ammonium molybdate or molybdic acid of 50:20 to 70:40 and more preferably 60:25. Thus, by using a greater amount of tertiary amine salt as compared to the ammonium molybdate or molybdic acid, a significant amount of the tertiary amine salt will be present in the reaction product disclosed in Schreiber. As such, nothing in Schreiber would lead one skilled in the art to modify the suspension disclosed therein and arrive at the colloidal suspension comprising “(a) *a dispersed phase comprising a major amount of one or more dispersed hydrated polymeric compounds selected from ... polymolybdates ...* and, (b) an oil phase comprising one or more dispersing agents and a diluent oil” as generally recited in independent Claims 1, 18 and 43.

In addition, with respect to Claim 18, nowhere does Schreiber provide any suggestion or motivation of a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, (a) an aqueous solution comprising one or more hydrated polymeric compounds selected from the group consisting of polymolybdates, polytungstates, polyvanadates, polyniobates, polytantallates, polyuranates, and mixtures thereof; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 18.

Nor, with respect to Claim 43, does Schreiber provide any suggestion or motivation of a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, an (a) aqueous solution comprising (i) one or more monomeric compounds selected from the group consisting of molybdenum, tungsten, and vanadium containing compounds and (ii) an effective amount of an acid capable of at least partially polymerizing the one or more monomeric compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 43.

Nor, with respect to Claim 63, does Schreiber provide any suggestion or motivation of a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension” as presently recited in Claim 63.

Rather, as stated above, Schreiber simply discloses that the lubricant additive according to the present invention is preferably present as a package in the form of a solution or suspension in a primary oil (mineral or synthetic oil) and goes on to state in Example 2 that a lubricating agent package is produced by mixing 2 parts by weight of a reaction product obtained according to Example 1 (a) in mineral oil, 4 parts by weight of sulphonated ester and 2 parts by weight of



zinc dithiophosphate. At no point is there any disclosure, suggestion or even a hint in Schreiber of mixing the recited components (a)-(c) under agitation to obtain a micro emulsion, and heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension of Claims 18, 43 and 63. In contrast, Schreiber is simply forming a conventional additive package by mixing the lubricant additive obtained from the reaction product of a salt of a tertiary amine with ammonium molybdate and/or molybdic acid with an oil and other conventional additives. As such, nothing in Schreiber would lead one skilled in the art to modify the process of making the additive package disclosed therein and arrive at the presently claimed process of preparing a stable colloidal suspension as presently recited in Claims 18, 43 and 63. Accordingly, Claims 18, 43 and 63 are believed to be further patentable over Valcho et al.

Furthermore, with respect to Claim 63, nowhere does Schreiber provide any suggestion of motivation of a process for preparing a stable colloidal suspension comprising:

“mixing, under agitation, (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of *niobium, tantalum, and uranium containing compounds*; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and,

heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension comprising (a) a dispersed phase comprising a major amount of a dispersed hydrated polymeric compound selected from the group consisting of *polyniobates, polytantalates, and polyuranates*; and, (b) an oil phase comprising the dispersing agent and the diluent oil” as presently recited in Claim 63.

Rather, as stated above, Schreiber simply discloses a lubricant additive obtained from the reaction product of a salt of a tertiary amine with ammonium molybdate and/or molybdic acid. At no point is there any suggestion, motivation or even a hint in Schreiber of mixing (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds, with (b) one or more dispersing agents and (c) a diluent oil to form the recited colloidal suspension. In contrast, the primary goal of Schreiber was to prepare the reaction product of a salt of a tertiary amine with ammonium molybdate and/or molybdic acid. Thus, nothing in Schreiber would lead one skilled in the art to modify the reaction product disclosed therein and arrive at a process to prepare a colloidal suspension by "mixing, under agitation, (a) an aqueous solution comprising one or more monomeric compounds selected from the group consisting of niobium, tantalum, and uranium containing compounds; (b) one or more dispersing agents and (c) a diluent oil to form a micro emulsion; and, heating the micro emulsion to a temperature to remove sufficient water so as to produce a stable colloidal suspension" as presently recited in Claim 63. Accordingly, Claim 63 is believed to be further patentable over Schreiber.

For the foregoing reasons, Claims 1, 2, 5-11, 14-19, 22, 23, 26-35, 37, 39-44, 49, 51, 54-63, 69 and 72-75 are believed to be nonobvious, and therefore patentable, over Schreiber. Accordingly, withdrawal of the rejection of Claims 1, 2, 5-11, 14-19, 22, 23, 26-35, 37, 39-44, 49, 51, 54-63, 69 and 72-75 under 35 U.S.C. §103 (c) is respectfully requested.

Appln. No. 10/675,631  
Response dated April 3, 2007  
Reply to Office Action dated January 3, 2007

For the foregoing reasons, Claims 1-75 as presented herein are believed to be in condition for allowance. Such early and favorable action is earnestly solicited.

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Michael E. Carmen". The signature is fluid and cursive, with the first name "Michael" being more prominent.

Michael E. Carmen  
Reg. No. 43,533  
Attorney for Applicants

M. CARMEN & ASSOCIATES, PLLC  
170 Old Country Road – Suite 400  
Mineola, NY 11501  
Phone: (516) 992-1848  
Facsimile: (516) 739-0981  
MEC:bg

**EXECUTIVE EDITOR**  
Jacqueline I. Kroschwitz

**EDITOR**  
Mary Howe-Grant

# ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY

FOURTH EDITION

VOLUME 16

MASS TRANSFER  
TO  
NEUROREGULATORS



A Wiley-Interscience Publication

**JOHN WILEY & SONS**

New York • Chichester • Brisbane • Toronto • Singapore

# CONTENTS

Matches	1	N
Materials Reliability	8	N
Materials Standards and Specifications	33	N
Meat Products	68	N
Medical Diagnostic Reagents	88	N
Medical Imaging Technology	107	M
Membrane Technology	135	M
Memory-Enhancing Drugs	193	M
Mercury	212	M
Mercury Compounds	228	M
Metal Anodes	244	M
Metallic Coatings	258	M
Metallurgy	313	M
Metal-Matrix Composites	392	M
Metal Surface Treatments	416	M
Metal Treatments	449	N
Methacrylic Acid and Derivatives	474	N
Methacrylic Polymers	506	N

This text is printed on acid-free paper.

Copyright © 1995 by John Wiley & Sons, Inc.

All rights reserved. Published simultaneously in Canada.

Reproduction or translation of any part of this work beyond that permitted by Sections 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner is unlawful. Requests for permission or further information should be addressed to the Permissions Department, John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158-0012.

## Library of Congress Cataloging-in-Publication Data

Encyclopedia of chemical technology/executive editor, Jacqueline

I. Kroschwitz, editor, Mary Howe-Grant. —4th ed.

p. cm.

At head of title: Kirk-Othmer.

"A Wiley-Interscience publication."

Includes index.

Contents: v. 16, Mass Transfer to neuroregulators

ISBN 0-471-52685-1 (v. 16)

1. Chemistry, Technical—Encyclopedias. I. Kirk, Raymond E. (Raymond Eller), 1890–1957. II. Othmer, Donald F. (Donald Frederick), 1904–. III. Kroschwitz, Jacqueline I., 1942–.

IV. Howe-Grant, Mary, 1943–. V. Title: Kirk-Othmer encyclopedia of chemical technology.

TP9.F685 1992

660.02—dc20

91-16789

## MOLYBDENUM COMPOUNDS

The chemistry of molybdenum, Mo, is among the most diverse of the transition elements. In its compounds, molybdenum exhibits coordination numbers from four to eight, oxidation numbers from -II to VI, and numerous states of aggregation (nuclearity). Molybdenum forms binary compounds with many nonmetallic elements, and a number of these, namely the halides, oxides, sulfides, carbides, nitrides, and silicides, are of technological interest. In contrast to its congeners, chromium and tungsten, molybdenum is found naturally in the form of its sulfide molybdenite [1309-56-4],  $\text{MoS}_2$ . Similarly, in the enzymes in which molybdenum is found, the active site Mo is generally in a high sulfur environment. This thio-philicity of Mo also plays a role in a number of its technological uses.

In biology molybdenum is a component of fertilizer and nutrient formulations (see FERTILIZERS; MINERAL NUTRIENTS). Over 20 enzymes have been found to have molybdenum as a component of their active sites. The roles of molybdenum in nitrogen fixation (qv) and nitrate reduction establish this metal as a key element of a biological nitrogen cycle. In technology various solid and soluble molybdenum compounds have found use in lubrication (see LUBRICATION AND LUBRICANTS); hydrosulfurization, hydrogenation, and oxidation catalysis; anticorrosion and coatings (qv); flame and smoke retardancy (see FLAME RETARDANTS); and various forms of pigmentation.

The most important molybdenum oxidation states are VI, V, IV, III, II, and 0. The higher oxidation states are usually characterized by molybdenum binding to electronegative atoms, such as oxygen and the halogens. The lowest oxidation states are largely in the realm of organometallic chemistry, wherein the Mo is bound directly to the carbon atom of carbon monoxide (qv), to organic phosphines, and/or to a variety of unsaturated carbonaceous ligands.

### Molybdenum(VI)

The chemistry of hexavalent molybdenum is very prominent in both biological and industrial systems. Oxygen coordination of molybdenum is most common in this oxidation state (1-3). Molybdenum trioxide [1313-27-5],  $\text{MoO}_3$ , is a key intermediate in the technological utilization of molybdenum (Fig. 1). In the refining of Mo, molybdenite ore,  $\text{MoS}_2$ , which contains tetravalent Mo, is first roasted in air to form impure  $\text{MoO}_3$ . The  $\text{MoO}_3$  is then reduced to the metal with hydrogen from 500-1150°C. The trioxide melts at 795°C but sublimes significantly below that temperature. The structure of  $\text{MoO}_3$  is a complex, layered arrangement in which each of the six-coordinate Mo(VI) atoms shares the face of an octahedron with another Mo(VI) atom. The  $\text{MoO}_3$  reacts with base to produce a variety of molybdate salts, the simplest of which are of the form  $\text{M}_2\text{MoO}_4$ . Sodium molybdate [7631-95-0] is an example. These water-soluble salts serve as the starting materials for the synthesis of a wide variety of compounds.

The molybdate ion,  $\text{MoO}_4^{2-}$ , is a  $d^0$ , four-coordinate, tetrahedral anion. The structure (Fig. 2a) resembles that of other Group 6 (VIB) and Group 16 (VIA) ions, such as  $\text{CrO}_4^{2-}$ ,  $\text{WO}_4^{2-}$ ,  $\text{SO}_4^{2-}$ , and  $\text{SeO}_4^{2-}$ . The discrete dimolybdate ion [19282-23-6],  $\text{Mo}_2\text{O}_7^{2-}$ , exists in  $\text{N}(\text{C}_4\text{H}_9)_4^+$  salts (see QUATERNARY AMMONIUM

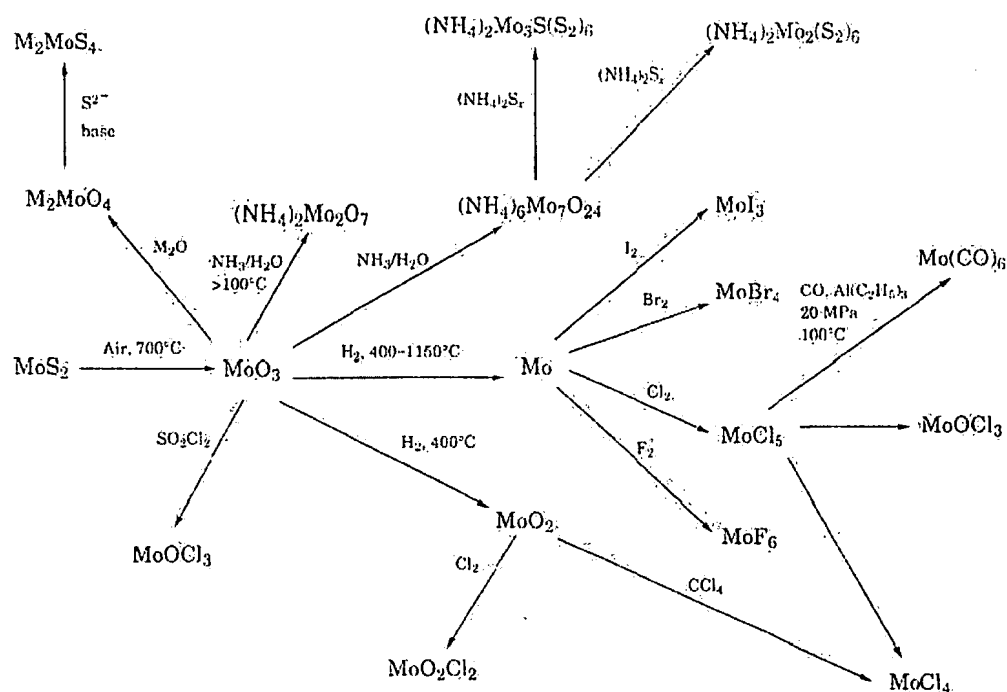


Fig. 1. Scheme for the preparation of technologically important compounds of molybdenum, where M = Li, Na, K, Rb, Cs, and  $\text{NH}_4$ . To convert MPa to psi, multiply by 145.

COMPOUNDS). Diammonium dimolybdate [27546-07-2],  $(\text{NH}_4)_2\text{Mo}_2\text{O}_7$ , available commercially as the tetrahydrate and prepared from  $\text{MoO}_3$  and excess  $\text{NH}_3$  in aqueous solution at  $100^\circ\text{C}$ , has an infinite chain structure based on  $\text{MoO}_6$  octahedra. In aqueous solution the behavior of  $\text{Mo}(\text{VI})$  is extremely pH-dependent. (4) Above pH 7 molybdenum(VI) occurs as the tetrahedral oxyanion  $\text{MoO}_4^{2-}$ , but below pH 7 a complex series of concentration-, temperature-, and pH-dependent equilibria exist. The best known of these equilibria lead to the formation of the heptamolybdate,  $\text{Mo}_7\text{O}_{24}^{6-}$  (Fig. 2h), and octamolybdate,  $\text{Mo}_8\text{O}_{26}^{4-}$  ions. Even larger aggregates may be present in solution and in salts. Both  $\text{Mo}_{12}\text{O}_{37}^{2-}$  and  $\text{Mo}_{36}\text{O}_{112}(\text{H}_2\text{O})_{16}^{8-}$  have been isolated and crystallographically characterized (4). At sufficiently low pH in very dilute solutions, cationic forms such as  $\text{MoO}_2^{2+}$  and  $\text{MoO}^{4+}$  are present.

The polymolybdate and heteropolymolybdate ions constitute a broad and commercially significant class. In these ions molybdenum is six-coordinate with octahedral geometry (4-8). Oxo ( $\text{O}^{2-}$ ) groups bridge the Mo atoms and serve as terminal ligands on some of the Mo ions. When other atoms are present during the acidification of molybdate solutions, a series of heteropolymolybdates is formed. For example, cations such as  $\text{Cr}^{3+}$  or  $\text{Co}^{2+}$ , or anions such as  $\text{PO}_4^{3-}$  or  $\text{AsO}_4^{3-}$ , form the heteropoly anions  $\text{H}_6\text{CrMo}_6\text{O}_{24}^{3-}$ ,  $\text{H}_6\text{CoMo}_6\text{O}_{24}^{4-}$ ,  $\text{PMo}_{12}\text{O}_{40}^{3-}$ , and  $\text{AsMo}_{12}\text{O}_{40}^{3-}$ , respectively. The yellow ion,  $\text{PMo}_{12}\text{O}_{40}^{3-}$ , is analytically useful, being formed in the molybdenum test for phosphate ion. Poly- and heteropolymolybdate ions are used in the precipitation of dyes. The protonated forms of the ions are strongly acidic and many poly- and heteropolymolybdate

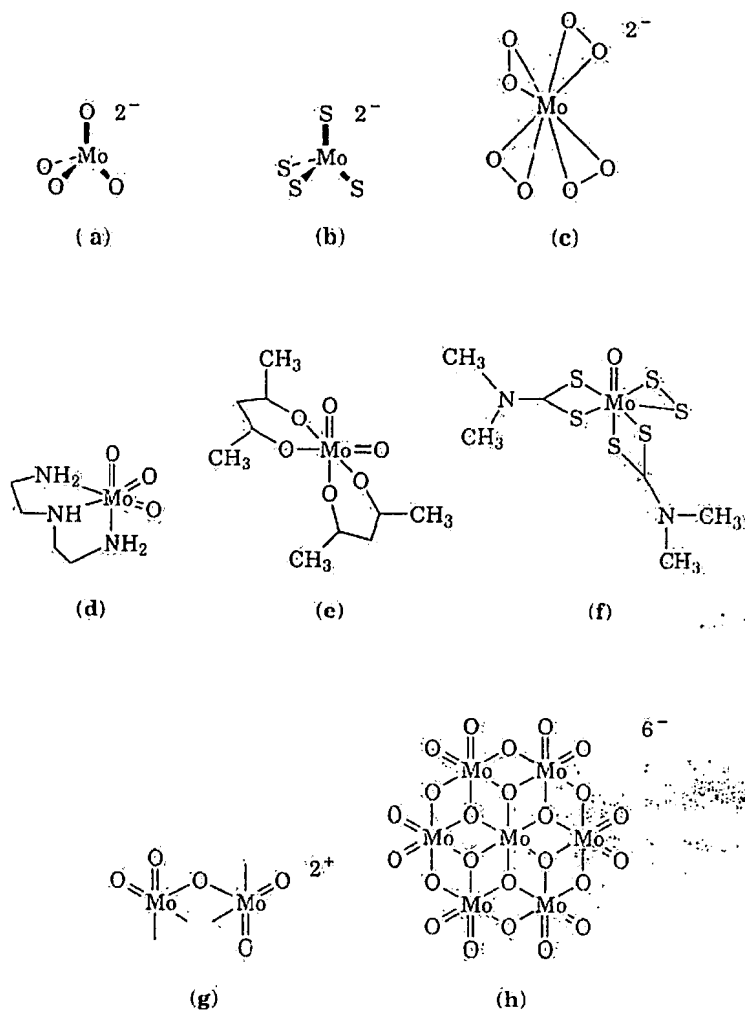


Fig. 2. Representative structures for compounds of molybdenum(VI): (a) molybdate(VI),  $\text{MoO}_4^{2-}$ ; (b) tetrathiomolybdate(VI),  $\text{MoS}_4^{2-}$ ; (c) tetrakis(peroxo)molybdate(VI),  $\text{Mo}(\text{O}_2)_4^{2-}$ ; (d) *cis*-trioxodiethylenetriaminemolybdenum(VI),  $(\text{MoO}_3(\text{dien}))$ ,  $\text{C}_4\text{H}_{13}\text{N}_3\text{MoO}_3$ ; (e) *cis*-bis(acetylacetonato)dioxomolybdenum(VI),  $\text{MoO}_2(\text{C}_5\text{H}_7\text{O}_2)_2$ ; (f) bis(dialkyldithiocarbamato)disulfidooxomolybdenum(VI),  $\text{MoO}(\text{S}_2)(\text{S}_2\text{CNR}_2)_2$  (R = alkyl); (g) the dinuclear core structure for  $\text{Mo}_2\text{O}_5^{2+}$  complexes; (h) heptamolybdate(VI),  $\text{Mo}_7\text{O}_{24}^{6-}$ .

compounds have catalytic activity that is attributable to their acid-base or redox properties.

The reduction of molybdate salts in acidic solutions leads to the formation of the molybdenum blues (9). Reductants include dithionite, stannous ion, hydrazine, and ascorbate. The molybdenum blues are mixed-valence compounds where the blue color presumably arises from the intervalence  $\text{Mo(V)} \rightarrow \text{Mo(VI)}$  electronic transition. These can be viewed as intermediate members of the class of mixed oxy hydroxides the end members of which are  $\text{Mo(VI)O}_3$  and  $\text{Mo(V)O}(\text{OH})_3$  [27845-91-6].  $\text{MoO}_3$  and  $\text{Mo(VI)}$  solutions have been used as effective detectors of reductants because formation of the blue color can



---

# COLLOIDAL SYSTEMS AND INTERFACES

---

**Sydney Ross**

Department of Chemistry  
Rensselaer Polytechnic Institute  
Troy, New York

**Ian Douglas Morrison**

Webster Research Center  
Xerox Corporation  
Webster, New York



A WILEY-INTERSCIENCE PUBLICATION

**JOHN WILEY & SONS**

NEW YORK • CHICHESTER • BRISBANE • TORONTO • SINGAPORE

A low man go.  
His-hu  
A high man  
M.  
BROWNING, /

This book is d  
FREDERICK  
by two

Best Available Copy

#### A NOTE TO THE READER

This book has been electronically reproduced from digital information stored at John Wiley & Sons, Inc. We are pleased that the use of this new technology will enable us to keep works of enduring scholarly value in print as long as there is a reasonable demand for them. The content of this book is identical to previous printings.

Copyright © 1988 by John Wiley & Sons, Inc.

All rights reserved. Published simultaneously in Canada.

Reproduction or translation of any part of this work beyond that permitted by Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner is unlawful. Requests for permission or further information should be addressed to the Permissions Department, John Wiley & Sons, Inc.

#### Library of Congress Cataloging in Publication Data:

Ross, Sydney. 1915-  
Colloidal systems and interfaces/Sydney Ross, Ian Morrison.  
p. cm.

"A Wiley-Interscience publication."  
Includes bibliographies and index.

ISBN 0-471-82848-3

1. Colloids. 2. Surface chemistry. I. Morrison, Ian.  
II. Title.

QD549.R65 1988

541.3'45--dc19

ISBN 0-471-82848-3

87-30529

CIP

Printed in the United States of America

10 9 8 7 6 5 4 3

## Processing Methods for Making Emulsions and Suspensions

Processing methods are of two types: those that emulsify or that pull agglomerates apart by shear forces and those that comminute aggregates by fracture. Different equipment is used for each process. Equipment to generate shearing forces need only provide sufficient energy to attenuate an immiscible liquid within another or to separate agglomerates. Comminution requires higher energy input to break tightly bound aggregates or to shatter coherent solids.

The generation of high-shear forces requires narrow gaps, or high rates of flow, or both. The following are examples of equipment in which one or the other of these modes to generate high-shear forces is used. A Banbury mixer, used to blend carbon and other fillers into rubber or plastics, functions at low speed with a loading of high millbase viscosity. The operation of a colloid mill, used to emulsify liquids, depends on flow through a narrow gap. A Kady mill, used to disperse powders in liquids, functions at high speed with a loading of low viscosity (Fig. E.1).

The breaking of aggregates requires impact, which is favored when unhindered by viscous resistance. The fineness of the grind depends on the size of the grinding media: the smaller the media, the finer the grind. Ball or pebble mills are rotated on a shaft or by rollers and the impacts are driven by gravity. Finer media require stirring.

Table E.1 lists high-shear mills in order of increasing viscosity of the millbase and high-impact mills in decreasing order of the size of the grinding media. Appendix K lists the names and addresses of some manufacturers of processing equipment.

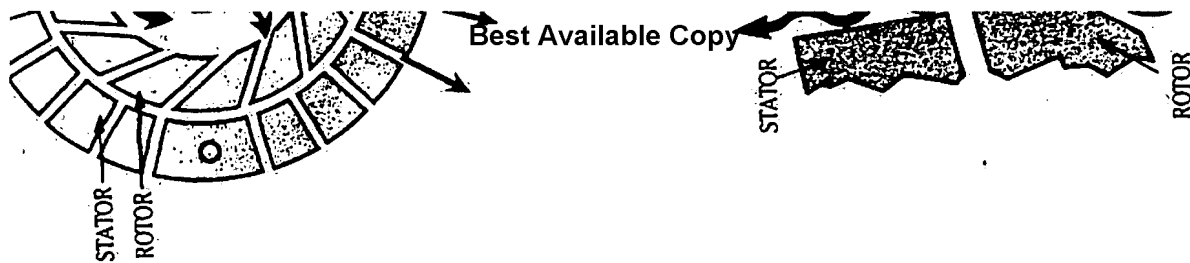


Figure E.1 A Kady mill rotor and stator

## CHAPTER IE

# Processing Methods for Making Emulsions and Suspensions

cessing methods are of two types: those that emulsify or that pull agglomerates apart by shear forces and those that comminute aggregates by fracture. Different equipment is used for each process. Equipment to generate shearing forces need only provide sufficient energy to attenuate an immiscible liquid in another or to separate agglomerates. Comminution requires higher energy input to break tightly bound aggregates or to shatter coherent solids. The generation of high-shear forces requires narrow gaps, or high rates of flow, or both. The following are examples of equipment in which one or the other of these modes to generate high-shear forces is used. A Banbury mixer, used to blend rubber and other fillers into rubber or plastics, functions at low speed with a long, narrow gap. The operation of a colloid mill, used to blend immiscible liquids, depends on flow through a narrow gap. A Kady mill, used to process powders in liquids, functions at high speed with a loading of low viscosity (E.1).

The breaking of aggregates requires impact, which is favored when unhindered viscous resistance. The fineness of the grind depends on the size of the grinding media: the smaller the media, the finer the grind. Ball or pebble mills are rotated about a shaft or by rollers and the impacts are driven by gravity. Finer media require stirring.

Table E.1 lists high-shear mills in order of increasing viscosity of the millbase. High-impact mills in decreasing order of the size of the grinding media. Appendix K lists the names and addresses of some manufacturers of processing equipment.

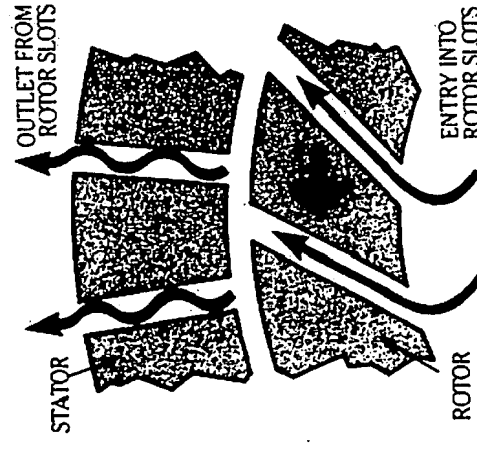
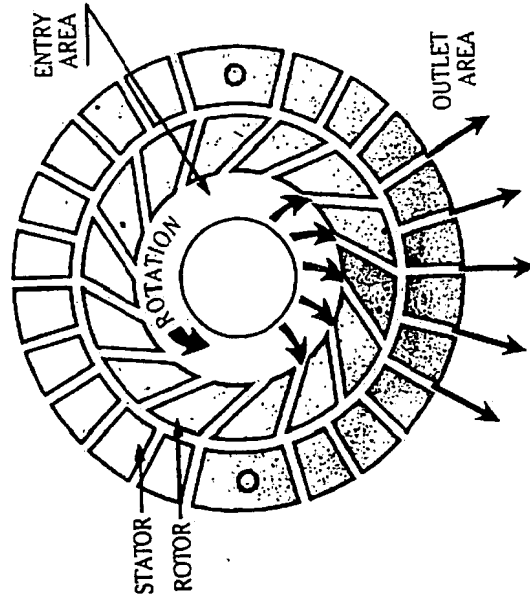


Figure E.1 A Kady mill rotor and stator. (Courtesy of the Kinetic Dispersion Corp.)

VariKinetic dispersers	Ball and pebble mills
Kady Mills	Attritor
Colloid mills:	
Microfluidizer	
Homogenizer	
Sonolator	
Ultrasonic mills	Sand mills
Three-roll mills	Dyno-Mill
Banbury mixer	

4000–5000 ft/min. Kady mills are contr turning within a labyrinth stator in which excess of 10,000 ft/min.

Colloid mills (Fig. E.2) operate by between a high-speed rotor and a stator. can rotate at speeds of 1,000–20,000 rpm surfaces is adjustable down to a thousar grooved. The liquids are recirculated ar

In the Microfluidizer two streams imp precisely defined microchannels within pressure can be varied from 500 to 20,0 velocities of 1500 ft/s. Fine droplets with by a combination of shear, turbulence equipment may be used to produce em

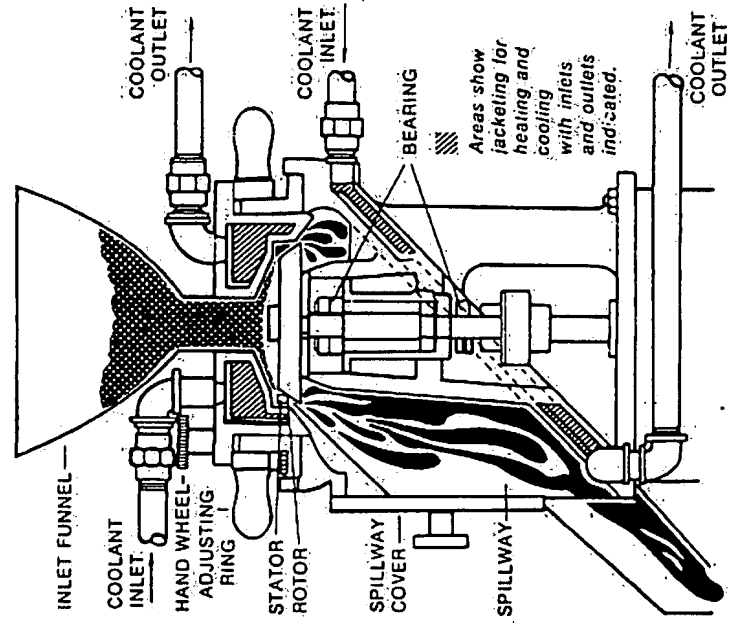


Figure E.2 Section of a vertical colloid mill. (Courtesy of the Premier Mill Corp.)

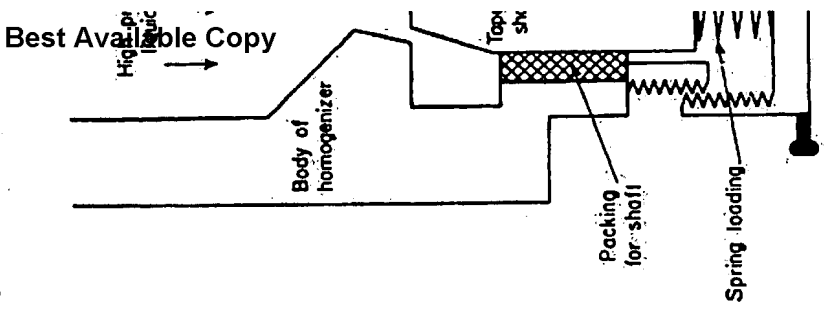


Figure E.3 Section of a single-stage

# 1. HIGH-SHEAR MILLS

Gaulin's VariKinetic disperser features variable-pitch impeller vanes, the angle of which can be adjusted while the unit is operating. The tip of the vanes moves at 4000–5000 ft/min. Kady mills are continuous mixers using a high-speed rotor turning within a labyrinth stator in which particles are accelerated to velocities in excess of 10,000 ft/min.

Colloid mills (Fig. E.2) operate by sucking liquids through a narrow gap between a high-speed rotor and a stator. The rotor is dynamically balanced and can rotate at speeds of 1,000–20,000 rpm. The gap between the rotor and stator surfaces is adjustable down to a thousandth of an inch. The rotor is sometimes grooved. The liquids are recirculated and the stator is water cooled.

In the Microfluidizer two streams impact at high velocity and high pressure in precisely defined microchannels within the interaction chamber. The process pressure can be varied from 500 to 20,000 psi; the process stream accelerated to velocities of 1500 ft/s. Fine droplets with a narrow size distribution are produced by a combination of shear, turbulence, impact, and cavitation forces. The equipment may be used to produce emulsions, suspensions, and foams.

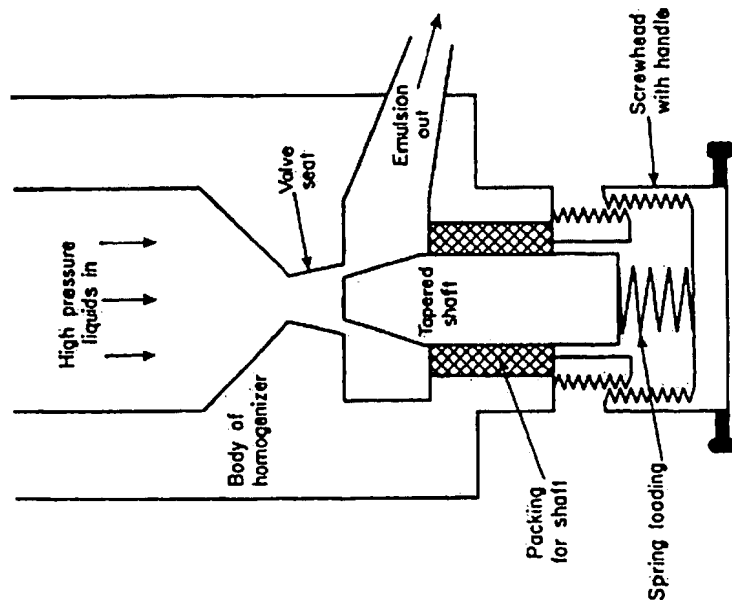


Figure E.3 Section of a single-stage homogenizer (Sherman, 1968, p. 11).

Table E.1 Classification of Milling Equipment

High-Shear Mills (creasing viscosity)	High-Impact Mills (decreasing media size)
VariKinetic dispersers	Ball and pebble mills
Colloid Mills	Attritor
Colloid mills	
Colloidizer	
Coltator	
Ultrasonic mills	Sand mills
Free-roll mills	Dyno-Mill
Imbury mixer	

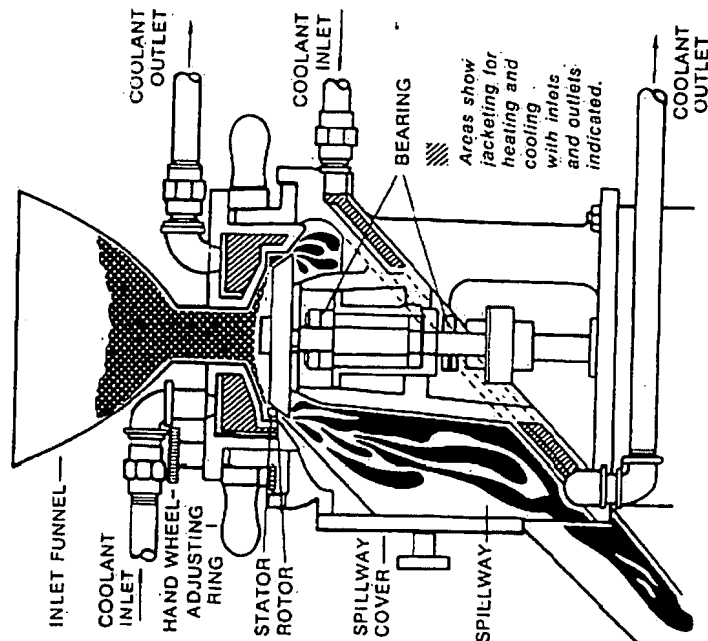


Figure E.2 Section of a vertical colloid mill. (Courtesy of the Premier Mill Corp.)

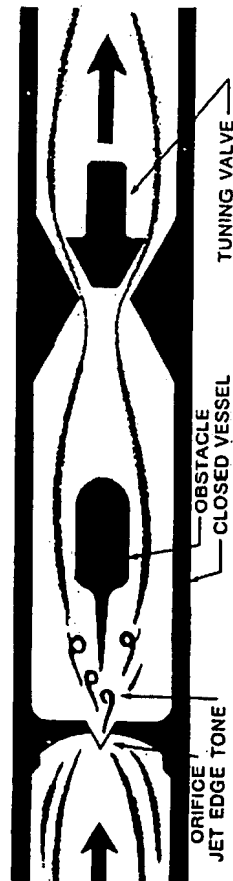


Figure E.4 Schematic diagram of the Sonolator. (Courtesy of the Sonic Corp.)

Homogenizers produce emulsions by forcing the mixture at high pressure (up to 2,000 psi) through a small orifice against a spring-loaded plunger (Figure E.3). The velocity of the liquid through a small gap creates high-shear forces. The lack of moving parts makes it preferable to the colloid mill. A familiar application is to use the size of fat globules in milk.

A Sonolator is a variation of the homogenizer (Figure E.4). A jet of liquid at pressures between 200 and 2000 psi is pumped through an orifice against a delicate obstacle in the jet stream. The turbulent flow of the liquid causes the liquid to resonate at ultrasonic frequencies. A high level of cavitation, turbulence, and shear is the result. The Sonolator can be tuned while in operation to a peak of acoustic intensity.

Ultrasonic activators convert conventional 60-Hz line frequency to 20,000 Hz. High frequency is fed to an electrostrictive element, which converts the signal into mechanical vibrations in tips of various shapes called horns. The tip of the horn is immersed in the liquid in which the ultrasonic vibrations cause cavitation. The horns are primarily laboratory instruments. For continuous use the vibrating horns must be cooled.

A three-roll mill is a set of rolls rotating in opposite directions with a small clearance between the rolls. High-shearing action is exerted on the agglomerate, forcing it to break up. High viscosity of the loading is important for this type of operation; therefore, percent solids is kept as high as possible. Its advantages are that it handles viscous materials such as printing inks. The disadvantage is that it is open to the air and so cannot be used with volatile solvents.

The Banbury mixer or mill has two kneading arms or rotors encased in a mixing chamber that rotate in opposite directions and at different speeds. They are so shaped that the plastic mixture is pressed against the walls of the chamber, forming a wedge during the kneading operation. The wedge is continuously formed and broken, while the motion of the rotors ensures good mixing of the batch. The chamber is heated to mill polymers above their glass transition temperatures.

## 2. IMPACT MILLS

Micronizer is a dry-process machine in which particles are fluidized in two opposed streams of air from high-speed jet nozzles, which project particles against each other at high kinetic energies. The nozzles are precisely aimed—within

fractions of a second in degrees of arc. The carrier fluid pressure and feed materials are equivalent on both sides. The mixture is classified by being blown into a vortex. The smaller particles follow the streamlines of the air and exit with it; the larger particles are recirculated until ground small enough to escape. The equipment is well suited to break up soft solids such as carbon blacks, molybdenum disulfide, and polymers.

A ball mill is any rolling mill in which steel or iron balls are used as the grinding medium (Figure E.5). The cylinder is usually made of steel. A pebble mill uses flint

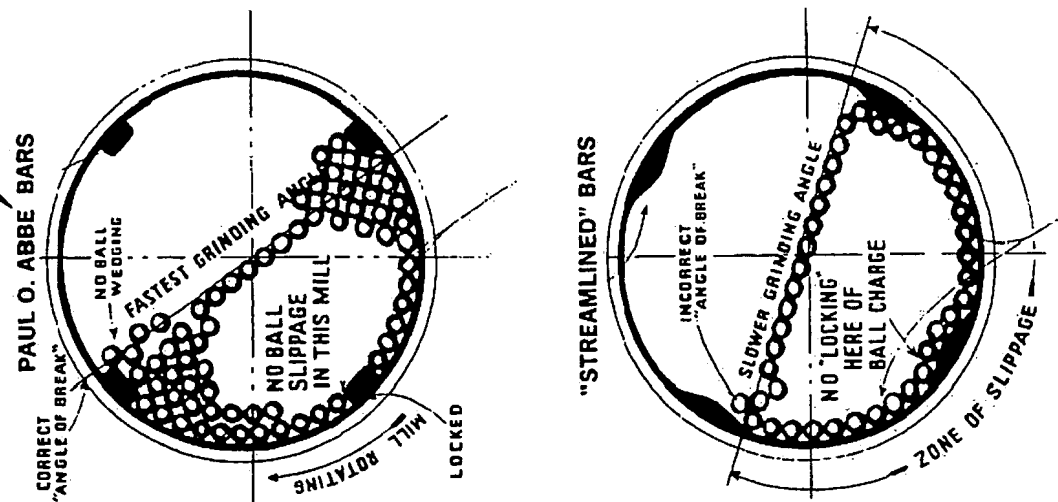


Figure E.5 Milling action in a ball mill. (Courtesy of Paul O. Abbé, Inc.)